U.S. NAVAL
MEDICAL RESEARCH LABORATORY

Submarine Base, New London, Conn.

Vol. XXII, No.18 REPORT NO. 416 24 November 1964

REPT. APPROVED
FOR PUBLICATION
NOV. 1963

PREDICTION OF ADJUSTMENT TO PROLONGED SUBMERGENCE ABOARD A FLEET BALLISTIC MISSILE SUBMARINE

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Benjamin B. Weybrew, Ph.D.

Bureau of Medicine and Surgery, Navy Department
Research Project MR005.14-2200-1.06

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SUMMARY PAGE

THE PROBLEM

To determine the relationship between the psychophysiological response patterns resulting from laboratory-induced stress and individual differences in the quality of adjustment of submariners during prolonged submerged cruises.

FINDINGS

Submariner adjustment is negatively correlated with general autonomic nervous system reactivity to laboratory-induced stress. Various combinations of psychophysiological indices with scores on a neuroticism scale were found usefully predictive of individual differences in adjustment. Finally, several personality dimensions related to submariner adjustment were tentatively identified.

APPLICATIONS

The results suggest that the kind of a person who adjusts most adequately to conditions of prolonged submergence not only can be described in terms of his trait "make up", but also in terms of certain functional characteristics of his nervous system.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Project MR005.14-2200-1, Selection Techniques Research. It is Report No. 6 on this Subtask, and is the fourth in the series dealing with prediction of adjustment; the previous three were NMRL Reports No. 383, 384, and 388. This report was approved for publication on 24 November 1963.

Published by the Naval Medical Research Laboratory
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(May be released as of 15 February 1964)

ABSTRACT

Fourteen psychophysiological indices of response to hyperventilation and breathholding and to discrimination-conflict stress were combined with measures of neuroticism, motivation, and aptitude to form a correlation matrix including adjustment ratings obtained from 200 men during two successive cruises aboard a nuclear submarine. Patterns of psychophysiological indicators with adjustment criteria were identified by factor variables resulted in Multiple R's ranging from .40 to .62. For the purpose of communication, these factors were labeled Limited Adjustment Potential, Optimal Adjustment Potential, Autonomic Resiliency, Autonomic Feedback, and Stress Responsivity. The structure of the factors suggested somatopsychological dimensions of use in personality assessment especially when selection of men for hazardous duty is involved.

TABLE OF CONTENTS

PREDICTION OF ADJUSTMENT TO PROLONGED SUBMERGENCE ABOARD A FLEET BALLISTIC MISSILE SUBMARINE IV. PSYCHOPHYSIOLOGICAL INDICES

INTRODUCTION

This is the fourth paper in a series of papers concerned with the complex problem of predicting individual differences in adjustment to the conditions existing during submerged periods, often exceeding 40 days, aboard a Fleet Ballistic Missile (FBM) submarine. The first of the papers in this series (Weybrew, 1962b) presented the results of a correlational study of some thirty or more criterion dimensions, largely trait ratings provided by Chief Petty Officers and Officers during one or more submerged patrols. A factor analysis of these rating criteria resulted in five factors, only two of which were identifiable. Estimation of scores on these two factors provided two criterion dimensions which appeared to provide a reasonably stable and usefully valid measure of individual differences in adjustment to submerged conditions. Appendix A presents tables depicting the factor structure of these two criterion factors which came to be utilized as adjustment criteria for several papers including the present study.

The second report in the series having to do with FBM personnel (Epstein, 1962) presented data relating background variables such as age, education, marital status and the like, to the rating scale criteria which identified the major criterion factors in this study. Briefly, according to these criteria, those men who adjusted most adequately to the submerged conditions were greater than 21 years or older, were second class petty officers or higher, were married, had had at least two years aboard fleet-type submarines, and had a history of broken service.

The third paper of this series (Parker, 1962) utilized as adjustment criteria factor scores estimated for each of the five factors described in the first paper of this series. This paper examined the predictive validity of several objective tests making up the submariner selection battery at the time the data for this study were collected. The results of that study appeared to be consistent with the majority of similar studies now in the literature, namely that objective personality tests, such as the "custom-tailored" Self-reported Motivational Questionnaire (SMQ) (Weybrew & Molish, 1959) and the Personal Inventory Barometer (PIB) (Weybrew & Youniss, 1957), have low but non-chance correlation with adjustment criteria*

* An example of a large scale study involving numerous and varied personality assessment tests and measurement techniques applied to Air Force officer selection may be found in MacKinnon, 1958.

As with the previous three studies, this study is based upon data collected from a sample of enlisted men from both crews of one FBM submarine (N=160-215). The rationale for this study is based upon two exploratory studies completed in the Laboratory (Weybrew & Alves, 1959a; Weybrew, 1962a). The first of the two studies suggested the possibility that electrodermal conductance (EDC) changes during and recoverability following hyperventilation and breathholding were significantly correlated with ratings on such personality traits as adaptability, emotional stability, excitability, motivation and the like. In the second study, a factor analysis of 29 psychophysiological indices showed a tendency for persons rated as emotionally stable and highly motivated to show significant increases in EDC and low changes in hand tremor during a pacing stress situation. Conversely, in the same study, persons who showed poor performance in the submarine training situation also showed low EDC and long discrimination time to a conflict situation demanding decisions as to which of the two lights was the brighter when the intensity differences were subtly reduced as the 16 trials progressed.

The literature contains relatively few studies aimed at identifying the complex interaction between autonomic nervous system (ANS) response patterns to induced stress, objective personality test scores, and criteria of adjustment to hazardous conditions. One such study cited as an example (Wenger, 1948) utilized some twenty peripheral indices of autonomic balance to identify differences in ANS function between 488 aviation students and 225 hospitalized Air Corps personnel who were described as convalescing from operational fatigue. Differences between the two groups were found for several autonomic indices such as palmar conductance, blood pressure and pulse.

More directly appropriate for this particular study were the correlations between the physiological indicators and personality factors reported by Wenger (1948) for an Air Force population of approximately 200 enlisted men. Although a number of the measures such as dermographic latency and body temperature showed low but non-chance correlation with several of the Guilford Factors STDCR and GAMIN, only two of the 39 correlations involving electrodermal indices were statistically significant.

It should be pointed out that all of these measures were obtained from subjects presumably in a basal state. In contrast, our working hypothesis stated previously (Weybrew, 1962a) is that if ANS indices are systematically related to personality trait configurations and, more importantly perhaps, to individual differences in adjustment to environmental stresses, the operational indices that will empirically demonstrate these relationships will most likely be found in underlying autonomic change-measures to imposed stress rather than in static autonomic measures obtained from humans presumably in a basal or resting state.

What is the rationale underlying the hypothesis that peripheral indices of autonomic nervous system function would be correlated with individual differences in the quality of adjustment to a hazardous environment such as found in the prolonged submerged submarine? Although we are not in agreement with Wenger, Jones and Jones (1956), that emotional behavior can be equated with autonomic processes, there appears to be little doubt that autonomic changes concomitant with and/or causal for emotions comprise an important class of processes making up emotional expression*. As indicated in previous work (Weybrew, 1962a), emotions are conceptualized as organismic response patterns to changes in environmental resistance to goal-directed (motivated) behavior**. As environmental resistance decreases, positive emotions such as elation, joy, and pleasurable excitment would be the expected outcomes. On the other hand, as environmental resistance to on-going behavior increases, negative emotions such as fear, anger, and disgust might be the expected result. Within this frame of reference, therefore, one would expect that in the closed ecology of the submarine in which a sizeable socially-circumscribed group is confined for prolonged periods of time, that many compelling motives would be blocked by the limitations of that environment. Similarly, in the same restricted environment, since the majority of the men maintain psychological resiliency and intactness for the prolonged confined periods, it appears that the submarine environment "opens up" so that other equally compelling motives are satisfied.

The literature already cited and other publications as well indicate the significance of individual differences in terms of autonomic response to a given environmental situation. Although admittedly a rather broad extrapolation from existing data, it would seem reasonable to expect that individual differences in the kinds and intensity of emotions experienced during the prolonged cruises (as inferred from functional ANS differences) would be related to the quality of adjustment to the same environment. Rather simply stated, therefore, this study is an attempt to determine whether individual differences in autonomic response patterns to laboratory-induced stresses are predictive of differences in quality of adjustment to the conditions existing during prolonged submergence.

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* Cognitive and affective aspects of the emotion-evoking situation together with skeletal muscular processes are also important classes of variables included in the processes termed emotional in our research.

** We have coined the term "behavioral inertia" to apply to this conceptualization of the emotions.

METHOD

Subjects

The sample size for the various correlations included in the study varied from N=160 to N=125 for most of the calculations, although it dropped to 43 for the computations involving peer ratings as criteria. The subjects were enlisted men from two crews of one Fleet Ballistic Missile submarine. The age ranged from 18 to 45 with a mean of 27. Sixty per cent were high school graduates. The mean Basic Battery scores ranged from 55 to 59 for the four subjects and were roughly equivalent to the 80th percentile in the distribution of Basic Battery scores for the Navy population at large. The distributions for all the above variables for the two crews making up the population sample were not significantly different, thus allowing the combination of the data from the two crews.

Tests and Apparatus

General Classification Test (GCT, 3.1).* A verbal test of intelligence, the score from which is highly correlated with the Wechsler Bellevue Verbal I.Q.

Personal Inventory Barometer (PIB, 3.2). A questionnaire similar to the Taylor Manifest Anxiety Scale but utilizing a multicategory response format (Weybrew and Youniss, 1957).

Self-reported Motivational Questionnaire (SMQ, 3.3). A questionnaire employing items "tapping" attitudes toward the Navy as a career and, in particular, attitudes toward the submarine service. It employs the same multicategory response technique as used in the PIB (Weybrew & Molish, 1959).

Skin conductance was recorded on the Multipurpose Polygraph Recorder No. 603 manufactured by Lafayette Instrument Company. Manufactured by the same company, a bridge circuit (Model 601A) was used to transmit skin resistance to the recorder. A precision helipot control, operated manually, provided a means of recording continuously the absolute resistance level of the subject. Provided also was a three-position selector, by means of which input impedance could be varied from 0 to 10,000 ohms, 0 to 100,000 ohms, and 0 to 1 megohm. Finger electrodes were connected by means of a commercial zinc salt electrode paste to the palmar side of the third and fourth fingers of the same hand.

* The parenthesis encloses the matrix number designation and abbreviations for the variables in Table I and II.

The conflict experiment involved the use of a standard light discrimination apparatus. Two lights, the intensity of which could be varied independently, were connected in series with a buzzer and an electric stop-clock accurate to the nearest 0.01 second. The lights, clock, buzzer and timer could be energized only by the experimenter and the circuit "broken" only by the subject's pressing a button.

Procedure

The procedure followed in the hyperventilation-breathholding experiment was similar to that employed in a previous study (Weybrew & Alves, 1959).* Four minutes were allowed for adaptation to the electrodes and the whole recording situation. Then four minutes were allowed to establish a basal conductance level, the bridge being balanced every minute and resistance recorded every 15 seconds. The subject was then instructed to "take in a deep breath, breathe it out; take in another, etc.", being careful to get three full inspirations and expirations and to hold the fourth as long as possible. The bridge was balanced immediately before the onset of the first hyperventilatory sequence, just before holding the fourth breath, and immediately after maximal breathholding. A 3-minute recovery period, with resistance readings taken every 15 seconds, followed the hyperventilation-breathholding sequence. Several derived scores were obtained from the resistance levels and resistance changes as follows:

1.1 Basal Conductance Level (B.L.) was the mean of 16 readings (units are micromhos) taken every 15 seconds for the 4-minute pre-experimental (basal) period.

1.2 Average Deviation (A.D.) was computed by summing the absolute deviations of the conductance readings taken every 15 seconds about B.L. (1.1) divided by the 16 readings.

1.3 Displacement Index (D.I.) was computed by the equation R.I. = M.C. - B.L./B.L. x 100, where M.C. = maximum conductance level observed during hyperventilation and breathholding.

1.4 Recovery Index (R.I.) was computed by the equation R.I. = M.C. - R.L./B.L. x 100, where R.L. = recovery level calculated as the mean of the 12 conductance readings taken every 15 seconds during the 3-minute recovery period following breathholding.

1.5 Recovery Quotient (R.Q.) was computed by the equation R.Q. = R.I./D.I.

* The sequency was the same for all subjects, with the hyperventilation-breathholding procedure preceding the conflict-stress situation.

1.6 Breathholding Recovery Slope (BH-RS) was taken as the slope (tangent) of the "best-fitting" line to the EDC tracing during breathholding. Almost without exception, EDC curves during breathholding are in the direction of lowered conductance (increase in resistance).

1.7 Autonomic Rebound Index (ARI) was computed from the galvanic skin response (GSR) following the termination of breathholding as follows: The number of ohms drop in resistance divided by the time (seconds) elapsed until the resistance "rebounds" to the EDC level existing at the termination of breathholding. For example, a GSR of 1000 ohms which "rebounds" to the EDC level at the termination of breathholding in 25 seconds would yield a score of 40 ohms/second. Although presented in more precise neurological language, Gellhorn (1957) uses the term "rebound" to describe a somewhat similar concept.

1.8 Breathholding Time (BHT) was recorded by stopwatch in seconds.

With electrodes still in place from the first experiment and after dark adapting for three minutes the subject was briefed for the second experiment. "Following the 'Ready' signal two lights will come on simultaneously with a loud buzzer. You are to decide as quickly as possible which is the BRIGHTER of the two. Signify that you have decided by pressing this button which turns off the lights and buzzer. Do this as quickly as possible after you have made the decision. Then say LEFT or RIGHT to indicate the brighter of the two. We will have a few practice trials so that you'll see what we mean." Five practice trials were allowed with the lights greatly disparate in terms of intensity. Then, with right and left randomized as to which was the brighter in each of the 16 experimental trials, the light intensity differences were reduced by 20 arbitrary units in each succeeding trial. For the last four trials the intensities were exactly equal. Having determined empirically that the intensity discrepancy on the 8th trial was approximately the difference limen, it was decided to call the first eight trials the minimal conflict trials and the last eight trials, those in which the intensity differences were less than the mean difference limen, the maximal conflict trials. The subjects were further told "even though the lights may seem equally bright, please try to decide which is the brighter as soon as possible and indicate your decision by pushing the button." The loud buzzer was used as a means of "pushing" the subject to make the discrimination in spite of the difficulty. The recovery period consisted of three minutes following the experiment. The room remained darkened during this period. The following scores were obtained for each person, matrix numbers being again listed:

2.1 Galvanic Skin Response (GSR), Minimal Conflict, (GSR-Min-Con), was the mean of the GSR's for the first eight trials.

2.2 GSR, Maximum Conflict, (GSR-Max-Con), was the mean of the GSR's for the last eight trials, coinciding with the most difficult discriminations.

2.3 Displacement Index to the Conflict Experiment, (DI-Con), was computed as the difference between GSR-Max-Con (2.2 above) and GSR-Min-Con (2.1) changed to per cent of the latter.

2.4 Recovery Index (Conflict), (RI-Con), was the difference between the mean of 12 basal conductance readings taken each 15 seconds of the 3-minute recovery period and the mean conductance level at the outset of each of the first 8 trials (minimal conflict) changed to per cent of the latter measure.

2.5 Discrimination Time, Minimal Conflict, (DT-Con), was equivalent to the mean discrimination time for the first 8 trials (units are .01 second).

2.6 Displacement Index, (DI-DT), was computed from the difference between the mean discrimination time for last 8 trials (maximum conflict) and mean discrimination time for the first 8 trials (minimum conflict) changed to per cent of the latter.

The criterion dimensions (4.1 and 4.2) were in the form of factor scores computed from the loading structures delineated by the factor analysis of twenty rating-scale dimensions and two self-reported attitudinal dimensions (Weybrew, 1962b). These data were collected during two FBM patrols. Estimated for the most significant first two factors (out of five), factor scores were obtained rather simply by summing each man's rating (in standard score form) for each of the high-loading variables on the factor in question, weighting each scale by its loading on the factor. Appendix A contains tables of factor loadings describing the structure of these two criterion factors

The procedure used in collecting and scoring the criterion data obtained by the peer nomination technique (not included in the factor analysis) was as follows: Nomination blanks were requested about midway of one submerged patrol. The task was to list and rank order the names of the three men highest rated in the trait and conversely the names of the three lowest rated men. The five dimensions were labeled Likability, Emotional Stability, Motivation Tension, and Submariner Potentiality. Each person's peer nomination score was computed by summing the number of times his name was listed among the three "most" likable, stable, etc., each nomination being weighted inversely (from 1 to 3) as to its rank order position. Weighted similarly, the same sum was computed for the nominations in the "least" category. Subtraction of the second from the first weighted sum provided the peer nomination score for each man.

RESULTS

The Correlation Matrix

Pearson correlation coefficients were computed for the fourteen psychophysiological variables, the three psychometric scores, and the two criterion factor scores. This correlation matrix is presented as Table I on the following page. As a result of linear dependence involved in the method of score derivation several of the correlation statistics in Table I are assumed to be spuriously high. Examples of inflated coefficients are found in the correlation between the Recovery Quotient and Recovery Index, variables 1.5 and 1.4 in that order, and between the latter and the Displacement Index (1.3). However, only three coefficients involving these scores reached significance (5% level). Not including these, 50 (29%) of the coefficients were significant at the same confidence level.

Although most of the correlational patterns will be delineated in the factor analysis to follow, there are nonetheless a few comments that would seem to be indicated. First of all, the correlation of .87 between the recovery index for the conflict experiment and the recovery quotient computed from the hyperventilation-breathholding data suggest the relative consistency of these indices derived from quite different experimental conditions. Secondly, the correlation of .86 between the Galvanic Skin Responses (GSR) to maximum and minimum discrimination conflict indicates that the magnitude of GSR is reliable from one part of the conflict experiment to the next. Thus GSR appears to have the consistency and distinctiveness to be included as a usefully-descriptive trait of personality. Moreover, tending to support the trait hypothesis are the correlations between basal conductance and GSR across the two experiments (intercorrelations among variables 1.2, 2.1, and 2.2 in Table I).

At least of passing interest is the tendency for verbal intelligence (GCT, variable 3.1) to be systematically related to EDC and GSR derived scores from the two experiments. That this is not a spurious finding is argued by the fact that six of the eleven coefficients of GCT with the electrodermal variables reach significance at the 5% level.

As derived, the two factor scores (4.1 and 4.2 in Table II) included as criteria obviously are redundant since in effect approximately 90% of the variance is common to both. Inspection of several other correlational patterns in Table I provide additional relationships with "hypothesis-generating" characteristics. However, the factor analysis to follow will provide a clearer delineation of these patterns and hopefully suggest the directions further research of this kind should take.

Table I

Intercorrelation of the Psychophysiological Indices and Selected Test Scores with the Adjustment Criterion Factors[a]

Variables	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	2.1	2.2
1. Hyperventilation Breathholding Indices										
1.1 Basal Conductance Level (BL)[b]	...									
1.2 Average Deviation (AD)	-06									
1.3 Displacement Index (DI)	-06	00								
1.4 Recovery Index (RI)	05	01	41**							
1.5 Recovery Quotient (RQ)	04	-02	-04	50**						
1.6 Breathholding Recovery Slope (BH-RS)	19**	01	18**	36**	18**					
1.7 Autonomic Rebound Index (ARI)	-14	08	82**	23**	21**	33**				
1.8 Breathholding Time (BHT)	-07	05	-09	-07	-23**	-03	09			
2. Discrimination Conflict Indices										
2.1 GSR (Minimal Conflict)	-33**	08	17	27**	16*	44**	42**	-06		
2.2 GSR (Maximal Conflict)	-34**	10	18**	26**	12	43**	47**	04	86**	
2.3 Displacement Index Conflict (DI-Con)	09	-02	03	-02	-03	-06	-02	-03	-17*	-07
2.4 Recovery Index(Conflict) (RI-Con)	-09	02	-16*	-04	87**	-04	-01	14*	02	-04
2.5 Discrimination Time(Conflict)(DT-Con)	03	08	15*	09	27**	-05	01	-22**	-14*	-13
2.6 Displacement Index (DI-DT)	-07	05	02	07	02	04	05	03	-04	04
3. Test Variables										
3.1 General Classification Test (GCT)	-07	-02	-29**	-26**	-24**	-01	-07	06	-14*	-06
3.2 Personal Inventory Barometer (PIB)	09	-05	02	.05	03	-13	12	11	12	20*
3.3 Self-reported Motivational Questionnaire (SMQ)	-11	05	10	11	06	-01	20*	14*	-14*	-06
4. Criterion Factors										
4.1 Favorable Trait Configuration I	18*	-02	-34**	03	07	-12	-05	-06	00	08
4.2 Favorable Trait Configuration II	18*	-10	-34**	25**	-04	-15*	-02	-09	02	07

Footnotes are on the last page of the table.

Table I (Continued)

	Variables	2.3	2.4	2.5	2.6	3.1	3.2	3.3	4.1	4.2
	2.4 Recovery Index (Conflict)(RI-Con)	09								
	2.5 Discrimination Time(Conflict)(DT-Con)	09	-05							
	2.6 Displacement Index (DI-DT)	12	13	-04						
3.	Test Variables									
	3.1 General Classification Test (GCT)	-20*	-16*	-14*	-07					
	3.2 Personal Inventory Barometer (PIB)	07	02	01	02	-02				
	3.3 Self-reported Motivational Questionnaire (SMQ)	12	00	-01	-05	-12	-03			
4.	Criterion Factors									
	4.1 Favorable Trait Configuration I	00	04	19**	-15*	18*	-20**	-08		
	4.2 Favorable Trait Configuration II	-20**	06	-04	-09	14	-22**	00	95**	...

[a]The population sample was 215 for the intercorrelation of variables 1.1 through 2.2. N=160 to 170 for all coefficients involving variables 2.3 through 4.2. Decimals are omitted.

[b]A brief description of each of the variables included in the matrix is contained in the Methods and Procedure section of this report.

[c]* and ** indicate Pearson correlation coefficients significant at the 5% and 1% level respectively.

The Factor Matrix

With communalities estimated from the highest column correlation, the Thurstone group centroid method of factor analysis was applied to the 19 x 19 correlation matrix presented in Table I. Five reference axes were extracted from the matrix and rotated orthogonally* for simple structure. This rotated factor matrix is presented in Table II.

Table II - Rotated Factor Matrix[a]

	Variables	Orthogonally Rotated Factor Loadings					
		F_1[c]	F_2[c]	F_3[c]	F_4[c]	F_5[c]	h^2
1.1	Basal Conductance Level (BL)[b]	-380	129	012	-273	-050	238
1.2	Average Deviation (AD)	075	-060	-010	025	035	011
1.3	Displacement Index (DI)	154	-257	-110	-237	823	835
1.4	Recovery Index (RI)	261	218	247	-399	382	482
1.5	Recovery Quotient (RQ)	185	104	891	-325	069	949
1.6	Breathholding Recovery Slope (BH-RS)	513	042	070	001	230	323
1.7	Autonomic Rebound Index (ARI)	362	027	040	090	829	829
1.8	Breathholding Time (BHT)	-046	-066	003	432	060	197
2.1	GSR (Minimal Conflict)	932	149	-048	-032	026	895
2.2	GSR (Maximal Conflict)	882	183	-085	055	132	839
2.3	Displacement Index Conflict (DI-Con)	-125	-212	-003	-165	003	088
2.4	Recovery Index (Conflict) RI-Con)	102	-056	924	182	188	936
2.5	Discrimination Time (Conflict)(DT-Con)	-080	-137	127	-390	064	198
2.6	Displacement Index (DI-DT)	045	-135	105	014	020	032
3.1	General Classification Test (GCT)	-083	213	-160	378	-154	244
3.2	Personal Inventory Barometer (PIB)	115	-186	008	-023	-023	049
3.3	Self-reported Motivational Questionnaire (SMQ)	-091	-086	121	119	267	116
4.1	Favorable Trait Configuration I	-129	889	-001	021	-127	824
4.2	Favorable Trait Configuration II	-187	972	-021	-070	-020	986

[a]The transformation matrix used for the orthogonal rotations may be found in the Appendix B.

[b]A brief description of each of the variables including the procedure for score deviation may be found in the Method section of this report.

[c]Tentative labels for factors: F_1, Limited Adjustment Potential; F_2, Optimal Adjustment Potential; F_3, Autonomic Recoverability; F_4, Autonomic Feedback; F_5, Stress Responsivity.

* The transformation matrix describing the rotations is presented as Appendix B.

Somewhat arbitrarily, a factor loading equal to or greater than .18* was used as the criterion for inclusion of the variables used to delineate the structure of the rotated factors. Factor loadings for the identifying variables are underlined in Table II.

Looking first at the loading patterns of the variables we see that the communalities for four of the variables approach zero (variable numbers 1.2, 2.3, 2.6, and 3.2) and therefore are assumed to be unique in the present factor matrix.

For the purpose of delineating more clearly the structure of the factors the identifying variables i.e., those with significant loadings were combined by factor (Table III). Included also in this table is a statement indicating the relevance of the sign and the magnitude of the variable loadings.

TABLE III - Structure of the Five Factors

F_1, Tentative Label:		Limited Adjustment Potential
Matrix Number	Factor Loading	Variable Content[a]
2.1	.932	Large Electrodermal Responses (Minimal Conflict)
2.2	.882	Large Electrodermal Responses (Maximum Conflict)
1.6	.513	Steep Slope to EDC Recovery Curve
1.1	.380	Low Basal Conductance Level
1.7	.362	High Autonomic Rebound Index
1.4	.261	Moderately High Recovery Index
4.2	.187	Tendency to receive unfavorable Adjustment Ratings
1.5	.185	Moderately High Recovery Quotient

F_2, Tentative Label:		Optimal Adjustment Potential
Matrix Number	Factor Loading	Variable Content[a]
4.2	.972	Favorable Trait Ratings (I)
4.1	.889	Favorable Trait Ratings (II)
1.3	-.257	Low EDC Displacement (Breathholding)
1.4	.218	High EDC Recovery Index
3.1	.213	High GCT Scores
2.3	-.212	Low EDC Displacement to Conflict
3.2	-.186	Low Neuroticism Test scores

* Since centroid loadings are correlation coefficients, it seemed reasonable with N equal to 150 or more to assume that a loading was significant if it was as large as a 5% coefficient in Table I.

TABLE III - Continued

F_3, Tentative Label:		Autonomic Recoverability
Matrix Number	Factor Loading	Variable Content[a]
2.4	.924	High EDC Recovery Index (Conflict)
1.5	.891	High EDC Recovery Quotient (Breathholding)
1.4	.247	High EDC Recovery Index (Breathholding)

F_4, Tentative Label:		Autonomic Feedback
Matrix Number	Factor Loading	Variable Content[a]
1.8	.432	Long Breathholding Time
1.4	-.399	Low EDC Recovery Index
2.5	-.390	Short Discrimination Time (Conflict)
3.1	.378	High General Classification Scores
1.5	-.325	Low EDC Recovery Quotient
1.1	-.273	Low Basal EDC
1.3	-.237	Low Displacement Index (EDC)
2.4	.182	Slight tendency for EDC Recovery (Conflict)

F_5, Tentative Label:		Stress Responsivity
Matrix Number	Factor Loading	Variable Content[a]
1.7	.829	High Autonomic Rebound Index
1.3	.823	High Displacement Index
1.4	.382	Relatively high Recovery Index (Breathholding)
3.3	.267	High Motivation Scores
1.6	.230	Steep EDC Recovery Slope
2.4	-.188	Low Recovery Index (Conflict)

[a]Content statement takes into account the sign of the loading

The content of the variables significantly loading the first factor (F_1), i.e., those loadings underlined in Table II, provides some suggestions as to the structure of this factor. First of all, the highest loading variables are the mean GSR's obtained to both the minimum and maximum stress conditions in the conflict experiment. The hypothesis that the factor is related to the general lability of the sympathetic nervous system (at least as is indicated by EDC level and magnitude of GSR's) is supported by the excellent fit of variable 1.6 indicating a steep rate of recovery of resistance lost during breathholding. Further substantiation for the lability concept as associated with the structure of F_1 are the loadings of RQ (variable 1.5) and the recovery index (variable 1.4) obtained in the breathholding experiment. It is important to note that this functional resiliency and lability is found in people whose basal conductance level (variable 1.1) tends to fall in the lower end of the distribution. Finally, although based upon rather low factor loadings, the tendency for persons receiving high scores in this factor to receive low criterion factor ratings at least suggests that the pattern of functional autonomic resiliency suggested by the structure of F_1 may be of use in the screening of men with marginal adjustment potential for prolonged submerged duty.

It should be noted in passing that a previous factor analytical study (Weybrew, 1962b) disclosed a factor identified by low achievement indices in a military technical school. It was structurally similar to F_1 in terms of low activation level but was not loaded by the ANS resiliency indicators found in this study. Though tenuous at best, it may be that these discrepancies can be explained by differential emotion-inducing characteristics existing in academic situations as compared to prolonged submerged conditions. It is important to reiterate, however, that low basal EDC scores were common to both situations.

The second factor (F_2) was identified most significantly by favorable trait ratings (4.1 and 4.2). One may ask what functional characteristics of the autonomic system are correlated with favorable adjustment as indicated by ratings obtained during prolonged submergence? In contrast to the findings of a previous study (Weybrew 1962a), low not high EDC displacement both to the conflict and the breathholding situations (scores labeled 2.3 and 1.3 in that order) appear to be identifying variables for this factor. Since low displacement indices are found, the recovery indices should not appear. This is true for the Conflict Situation but not for the Recovery Index (R.I., 1.4) to the breathholding situation. Finally, high scores on F_2 show low EDC changes between maximum and minimum conflict stress (2.3) nevertheless they tend to show somewhat larger GSR's to a situation demanding difficult intensity discriminations (2.2). In addition, persons who obtain high scores in F_2 tend to admit fewer neurotic symptoms as measured by the PIB questionnaire (3.2). Finally, by virtue of the fact that the verbal intelligence score (GCT, 3.1) correlates with favorable trait ratings, this test score tends to load this particular factor.

Only three variables have sufficient factor weights to be considered in the discussion of the structure of F_3. It is not surprising that the recovery quotient from the breathholding experiment and the recovery index from the discrimination conflict experiment both yield high loadings on this factor since it may be recalled that the two scores showed a correlation coefficient of .87 (Table I). The goodness of fit to the F_3 hyperplane suggests that autonomic recoverability (resiliency) as measured by EDC indices derived from both stress situations is unrelated to displacement indices obtained under stress conditions as well as to the tests and adjustment criteria utilized in this study.

With five of the seven identifying variables for F_4 overlapping either F_1 or F_2, the structure of F_4 cannot be discussed apart from its interrelationship with these factors. Like F_2, F_4 is characterized by low displacement indices and is similar to F_2 in terms of low basal conductance scores. With low displacement indices loading this factor, it would be expected that the recovery indices, since there is less conductance change to recover, would be low. The significant negative loadings of the recovery index (1.4) and the recovery quotient (1.5) attests to this fact.

Three additional identifying variables for F_4 remain to be discussed. It is interesting to note that long breathholding time (1.8) falls squarely into the F_4 plane. The explanation of this finding is not immediately evident, however it may be that persons whose autonomic systems tend to be relatively unresponsive to laboratory-induced stress (low basal and recovery indices) experience less noxious sensations during breathholding. Too, it is within the realm of possibility that the patterning of autonomic indices with the breathholding score reflects individual differences in the feedback mechanisms of the autonomic system upon certain central processes underlying consciousness.

The reasonably good fit of verbal intelligence scores (GCT, 3.1) to the hyperplane of F_4 is interesting even if not immediately explainable. It could be that the more intelligent subject may perceive the experimental situation somewhat differently than the less intelligent person, and as a result, may "try harder" during the breathholding situation. Moreover it may be that this same person is more responsive and alert to the whole situation as indicated by the relatively short discrimination time demonstrated in the light discrimination task. This is indicated by the negative loading of discrimination time in the conflict situation, (2.5). All in all it seems a tenable hypothesis that F_4 contains autonomic, motivational, and intellectual components, complexly interrelated, though independent of the adjustment criteria utilized in this study.

The final factor to be identified from the rotated solution appears to be "marked" by high displacement scores to the breathholding situation (1.3), by high Autonomic Rebound Indices (1.7), and by a steep recovery slope

(1.6). The absence of indices of displacement obtained from the discrimination conflict experiment from the loading pattern for this factor suggests that this factor may be a physiological index of a autonomic function rather than a psychophysiological indicator. This statement is based upon the assumption that the autonomic response patterns to the breathholding experiment are less confounded with certain cognitive components presumably involved in the discrimination experiment. Apparently, persons receiving a high score in this factor tend also to show only moderate EDC recovery (1.4).

Though based upon a variable with very low communality, the loading of the motivational score (SMQ, 3.3) may be construed to indicate some complex relationship between the aspects of motivation "tapped" by this questionnaire and individual differences in sympathetic nervous system reactivity to stresses with low cognitive weighting.

Correlation of Predictors with Peer Rating Criteria

The interrelationships of peer rating criteria with supervisory ratings both obtained from the same two FBM crews during prolonged submergence are discussed in a previous report (Weybrew, 1962b). In spite of the fact that peer ratings were obtainable from only about one-third of the complement of the FBM crews used in this study, it was decided to investigate the correlation of the predictor battery with these criteria. Accordingly, the Pearson correlation coefficients for the 17 predictors with scores obtained by means of the peer nomination technique are contained in Table IV.

One fact should be emphasized in discussing these data namely that the correlational statistics are based upon a relatively small sample of the total population. This sample was defined largely by the "willingness" of the men to provide peer nominations according to the instructions outlined in the procedure section of this paper. As a result, one cannot exclude the possibility that a very "sharp" bias may have resulted from this sampling procedure.

Accordingly, the men receiving favorable nominations with respect to emotional stability received high motivation scores and also showed low displacement to discrimination conflict stress, but at the same time, showed incomplete recovery to the breathholding situation.

The correlation coefficient of .35 of peer ratings with respect to motivation and the Displacement Index (1.3) obtained during the breathholding experiment is interesting but due to the fact that only one out of seventeen of the correlational statistics met the 5% confidence criterion one is inclined to suspect the reliability of this particular finding. Tending to support this finding however is the fact that peer ratings with respect to motivation

Table IV - Correlation of the Predictor Variables with the Peer Rating Criteria

	Predictor Variables	Peer Ratings				
		Likability	Emotional Stability	Motivation	Tension	Submariner Potentiality
1.1	Basal Conductance Level (BL) [a]	-03	16	-04	17	-05
1.2	Average Deviation (AD)	-19	-17	08	-09	-17
1.3	Displacement Index (DI)	08	-22	35*	06	08
1.4	Recovery Index (RI)	-10	-36*	-03	-32*	-12
1.5	Recovery Quotient (RQ)	-05	-25	03	-11	-01
1.6	Breathholding Recovery Slope (BH-RS)	-15	02	06	-08	16
1.7	Autonomic Rebound Index (ARI)	16	-14	-09	-09	08
1.8	Breathholding Time (BHT)	13	18	12	12	14
2.1	GSR (Minimal Conflict)	-13	-16	19	-06	02
2.2	GSR (Maximal Conflict)	-17	-11	-04	02	-09
2.3	Displacement Index Conflict (DI-Con)	-11	-33*	-01	-40**	-08
2.4	Recovery Index (Conflict) (RI-Con)	-03	01	-13	04	-12
2.5	Discrimination Time	00	12	14	20	11
2.6	Displacement Index (DI-DT)	-07	-05	02	-10	-02
3.1	General Classification Test (GCT)	24	31	27	19	17
3.2	Personal Inventory Barometer (PIB)	04	-01	-11	06	-10
3.3	Self-Reported Motivational Questionnaire (SMQ)	19	41**	07	09	20

[a]See procedure section for description of the variables abbreviated in the table. N=43 except for variables 3.2 and 3.3 (N=55).

**Statistically significant at or beyond 1% level.

* Statistically significant at or beyond 5% level.

tended to load a factor identified by high displacement indices in a previous study (Weybrew, 1962a).

The two significant coefficients between peer rated tension and the Recovery Index (1.4) and the Displacement Index from the discrimination conflict experiment (2.3) are suggestive. It should be noted at the outset that the negative signs attached to the coefficients result from the fact that persons obtaining a high peer rating score with respect to this dimension do so by virtue of the number of nominations for "least tense" as opposed to the remaining peer rated dimensions wherein the nominations were for "most likable", "most emotionally stable", and "most highly motivated". Ascordingly, the least tense person appears to show greater GSR responses to discrimination conflict and show more complete EDC recovery to the breathholding situation. It should however be noted that such correlational relationships were not found in a previous study utilizing the same kind of criterion data (Weybrew, 1962a).

One finding that is inconsistent with the previous study mentioned immediately above is that none of the psychophysiological indices used in the present study correlated with peer nominations as to the "best" submariner. However, one would not feel justified in rejecting the possible predictive relationships on the basis of inability to replicate them in the present study largely because of the fractionated population sample from which peer ratings were attainable. Had peer nominations been available from at least a majority of the FBM crews utilized in this study and had these results been essentially negative, one would then feel more confident in rejecting the possible predictive relationships previously reported.

Multiple Predictive Validity

The question arises as to the predictive utility of combinations of the variables identifying certain of the factors resulting from this analysis. Table V contains data relevant to this kind of analysis for F_2 and F_4.

Since the two adjustment criteria were clearly identified with F_2, it is not surprising that the most effective combination of predictors was found for variables identifying this factor. Looking at the second column from the right in Table V, it is seen that more than 17% (out of a total of 38.4% of the variance of the criterion predicted by the regression equation) was attributable to individual differences in the Displacement Index to breathholding stress followed closely by the EDC Recovery Index to the same stress situation. Similarly, the two variables are equally predictive in the multiple regression computation for four variables identifying F_4. Different variable equations but none other than the two in Table V reached practical significance. Although cross validation is badly needed, these findings argue for

TABLE V - Multiple R's and Beta Weights for the Identifying Variables for Factor 2 and Factor 4[a]

Variables		Beta Weights	Predict-ability (Percent)	Multiple R
F_2:				
1.3[b]	Displacement Index	-.507	17.2	
1.4	Recovery Index	.489	12.2	.543[c]
3.2	Personal Inventory Barometer	-.221	4.9	.586
2.3	Displacement Index (Conflict)	-.143	2.9	.610
3.1	General Classification Test	.087	1.2	.620
F_4:				
1.3	Displacement Index	-.512	17.4	
1.4	Recovery Index	.459	11.5	.537
1.1	Basal Conductance Level	..133	2.4	.559
1.8	Breathholding Time	.086	0.8	.552

[a] The criterion used was the factor scores obtained from trait ratings during one or more prolonged submerged cruises.

[b] Refers to identifying number in Tables I and II.

[c] Calculated from Beta weights, the multiple R's are based upon combination of the variables in the row containing the coefficient plus those above it. (N=170), Wherry-Doolittle method.

the predictive utility of psychophysiological indices of this kind evaluated against rating criteria obtained from operating submarine crews.

DISCUSSION

In addition to providing a method "of distilling out" the most relevant variables from a complex variable domain, factor analysis often has an hypothesis-generating function. Accordingly, Table III provides some insight into the factorial composition of measures of the functional characteristics of the autonomic nervous system as determined by peripheral indicators obtained during laboratory-induced stress. The structure of F_2, labeled "Optimal Adjustment Potential", suggests generally that submariner enlisted men who obtain favorable trait ratings from Officers and supervisory Chief Petty Officers also show some tendency for low autonomic displacement to both the breathholding and discrimination conflict situations. Moreover, for persons obtaining high scores on this factor, the amount of displacement to stress in terms of EDC changes tends to be more completely recovered. In other words autonomic equilibrium seems to be characteristic of the optimally adjusted enlisted submariner during prolonged submergence. Furthermore, tending to substantiate the autonomic stability hypothesis is the finding that for those with high scores in F_2 the magnitude of GSR's is inversely related to the difficulty of light discrimination in the conflict experiment. Finally high scorers in F_2 tend to admit less frequent and severe symptoms on a neuroticism questionnaire as well as to obtain higher scores on a verbal intelligence test.

When one looks at the absolute magnitude of the loadings on F_2 however, it is seen that though the psychophysiological variables fall loosely in the F_2 hyperplane, they nonetheless, tend to have quite low factor loadings. As a result, the reliability of this particular factor structure may be less than adequate.

What then in fact are the relationships of functional autonomic indices to the criteria of adjustment to a stressful environment such as the submerged submarine? A previous study (Weybrew, 1962a) utilizing peer ratings as adjustment criteria produced a similar factor, again identified largely by favorable trait ratings. However, high rather than low, EDC displacement identified this factor. Are the differences in factor structure the results of differences in the method of inducing stress, the previous study having involved pacing on a psychomotor task? This possibility is not excluded by the results of this study.

The first factor was labeled "Limited Adjustment Potential" on the basis of a slight tendency for low (unfavorable) criterion trait ratings to fall within this plane. One has some basis therefore for arguing that the loading configuration on F_1 describes certain psychophysiological indicants of less adequate adjustment to prolonged submerged cruises. Accordingly, those men who receive high scores on F_1, in addition to receiving low adjustment ratings, also show low basal EDC (1.1), large GSR's to conflict stress (2.1 and 2.2), and large autonomic rebound indices (1.7). Consistent with indicators of low activation level but with exaggerated ANS responsivity are the findings of high recovery indices (1.4 and 1.5) and a steep recovery slope following breathholding (1.6). One is inclined to hazard a guess that somewhat unfavorable adjustment ratings are found in people, who though showing low activation level in terms of basal EDC are at the same time quite labile in terms of the GSR's observed during discrimination conflict. Also, though electrodermal conductance changes are slight, those changes that do occur tend to be completely recovered following any kind of displacing situation.

Since F_1 and F_2 tend hypothetically at least to define operationally an adjustment continuum, it would seem necessary to differentiate between the loading patterns for the two factors. In common with both F_1 and F_2 is variable (1.4), high EDC Recovery Index, and, loading in opposite directions, the criterion trait rating (4.2). The relatively few psychophysiological variables with rather low loadings on F_2 (optimal adjustment) as compared to the number and substantial weights of the same kind of indices with respect to F_1 (less adequate adjustment) argue that ANS indicators of stress responsivity may be useful in predicting unfavorable adjustment but less predictive of those traits associated with favorable adjustment. Low EDC level and high lability seem to be characteristic of those men who tend to receive less favorable ratings during prolonged submergence.

F_4 like F_1 is loaded significantly by scores on the General Classification Test (3.1). It is interesting to note that of the eleven correlation coefficients of GCT scores with EDC indices, six are significant beyond the 5% level, all in a negative direction (Table I). Negative correlation of the Army General Classification Test with a similar autonomic factor was found in one previous study (Weybrew, 1959a and Weybrew, 1962a). Nevertheless, it appears that there is a margin of evidence indicating that certain peripheral indicators of autonomic function are negatively correlated with verbal intelligence test scores.

What possible explanations are there for the negative relationships between verbal intelligence test scores and indices of psychophysiological response to stress? One possible explanation centers around the relationship between emotional response and the cognitions associated with the laboratory-induced stress situation. The more intelligent person may associate different meanings with scientific experimentation and perceive the apparatus and its operators differently (less threatening, for example) as compared to the less intelligent subjects being exposed to the same situation. Assuming that psychophysiological indicators are reliably related to the intensity of emotional response, it appears plausible then that the patterns of autonomic indicators utilized in this study could be different for different levels of verbal intelligence, the more intelligent person showing less psychophysiological response to the stress conditions.

A more speculative explanation of this finding would be based upon the possibility of some common genetic influences operation for both classes of processes. It is now reasonably well substantiated that the major proportion of variance in intelligence is the result of hereditary factors (Burt and Howard, 1956). Likewise there is some evidence that individual differences in autonomic function are explained to a certain extent by genetic factors (Jost and Sontag, 1944). Are there some genetically determined enzymatic or other processes related both to intellectual and autonomic function? Though somewhat tenuous, this seems to be a possibility.

F_4, tentatively labeled "Autonomic Feedback", contains breathholding time as the variable most clearly identifying this factor. Persons who are able to hold their breath for long periods of time tend to show low electrodermal displacement, and low recovery to the breathholding situation but with some slight tendency for high recovery to the discrimination-conflict situation. Again a high GCT score tends to contribute to the structure of F_4. The argument for some sort of feedback mechanism operating within persons scoring high in this factor is based upon the notion that breathholding for most people is an unpleasant experience and upon the evidence that breathholding evokes autonomic displacement (Weybrew, 1959a). Those men who are able to hold their breath longer also are more aware of visceral autonomic changes which, in turn, affect awareness of the nocioceptive sensations. Thus a CNS-ANS feedback loop of sorts may be involved. As an aside,one might predict that people scoring high on this factor would also be more accurate in describing the subjective components of emotional response. The existing literature to some extent supports this point of view (Mandler, Mandler and Uviller, 1958).

F_5, labeled "Stress Responsivity", though unrelated to the adjustment criteria, appears to be an interesting dimension possibly related to individual differences in motivation for the submarine service. The motivational component of F_5 is inferred from the fact that the Self-reported Motivational Questionnaire (SMQ, 3.3) is identified with this plane. Persons who obtain high scores in the factor, therefore, show maximal autonomic response to breathholding, and tend to have steep EDC recovery curves following breathholding. There appears to be little question that this factor is identified by persons who show high autonomic rebound indices (1.7).

The patterning of variables on F_5 appears to be a fair example of the hypothesis-generating function of factor analysis. Why should the magnitude of GSR following breathholding (ANS rebound) be correlated with scores for an objective paper-and-pencil test "tapping" various attitudes related to the submarine service, interpersonal attitudes, and to the clarity of personal goals--all reported by the man himself and therefore, subject to denial and suppression? A previous paper (Weybrew, 1962a) presented an argument for viewing the concept of motivation as behavior directionality involving energy channelization toward obtaining goals or satisfiers appropriate for the prepotent need(s) operating in a given situation. In the laboratory-imposed stress situation, therefore, the most highly motivated subjects (all submariners), at least those men who obtain high scores on F_5 tend to mobilize more energy in the stress situation than do those men who obtain low scores. The indicants for this energy mobilization are assumed to be an extremely labile and resilient autonomic system as inferred from the high EDC displacement and rebound indices. Although more factorially pure measures of motivation as well as a more extensive sampling of ANS indicators are needed to validate the notion that exaggerated autonomic responsivity and resiliency are associated with high task motivation, the hypothesis nonetheless seems both plausible and relevant. It may be that the relatively recent finding that disproportionately more autonomically hyporeactive persons as indicated by the Funkenstein mecholyl test are found in groups diagnosed as schizophrenic. It may be that this change in ANS excitability is related to the rather obviated changes in motivation observed in patients belonging to this diagnostic class (cited in Gellhorn, 1957, 232f).

The highly significant loading of the Autonomic Rebound Index (1.7) on F_5 suggests an interesting possibility. It should be recalled that during hyperventilation most subjects show a decrease in palmar resistance ranging from 200 to 2000 ohms or more followed by a slow gain in resistance during breathholding as gauged by the Recovery Slope, (1.6). The ANS Rebound Index is the ratio of the magnitude of the GSR (drop in resistance) to time in seconds for EDC to reach the post-breathholding level. What is the explanation of this rebound phenomenon? It may be a rather clear operational index for Wenger's concept of relief as defined by a reduction in sympathetically innervated responses. Arguing for this possibility is the fact that forced breathholding is unpleasant for most people and that subjectively the first breath is indeed a relief. Also, if we can conceive of a PNS overflow in some way damping SNS activity (Wenger's notion of ANS overcompensation), it may be that the ANS rebound score as well as the Recovery Slope are indicative of individual differences in this overcompensatory function (Wenger & Jones, 1956, P. 268f and 347f). Arguing however that the score indicates SNS resiliency, is the fact that the Displacement Index is correlated 0.82 with rebound. Finally, and in the interest of parsimony, however, the rebound index may be nothing more than the result of a sudden relaxation of the chest muscles stretched by breathholding.

While the correlational data involving peer ratings as adjustment criteria were inconclusive, this method of evaluating individual differences in the trait composition of persons confined in circumscribed groups would seem to be commendable. This optimistic note stems from the opinion that members of the tightly-knit groups characteristically found in submarine crews have many opportunities to observe many and varied behavioral indicators in many different situations thus maximizing the probability that the traits that are observed are distinctive, persistent dimensions of personality.

A "caveat emptor" needs to be stated in discussing the results of multiple correlational analyses contained in Table V. It is a well-established fact that largely because of correlated error, the practice of computing Beta weights and multiple R's on the same population sample generally inflates the latter. Cross-validation would of course clear up the question of the reliability of these multiple R's.

However, for the purpose of this discussion, let us assume that these multiple predictive relationships are maintained on cross-validation. What is the theoretical explanation of these findings? As the weighting pattern for F_2 in Table V indicates, why do people who receive favorable adjustment ratings during prolonged submergence also tend to show small EDC changes to both stress situations, to show more complete EDC recovery, to demonstrate characteristically low EDC level, show moderate electrodermal lability to conflict, to report few neurotic symptoms, and to fall in the upper range of the intelligence test distribution? In general, we feel these data argue that observer ratings are based upon, among other things, overt indicators of emotional expression. Moreover, relevant mechanisms underlying overt emotional expression are to be found in the functional differences in the autonomic systems of the men being rated. Rather simply, these ANS differences were inferred from derived scores based upon one peripheral measure of ANS function, electrodermal conductance, its change to, and recovery from, induced stress. Quite probably utilization of other ANS indices such as "changes-to-stress" of blood pressure, pulse, respiration rate, skin temperature and others may add to the predictability of the battery of measures.

Mentioned in the introduction was the fact that most studies using autonomic indices, obtained during basal conditions, show little, if any, relationship to adjustment criteria (for example, Wenger's Air Force Study involving prediction of Adaptability Ratings of Airmen, 1948). This study largely utilized autonomic change-measures to induced stress rather than basal measures. Though admittedly not completely convincing, the correlation coefficients between the ANS derived scores and the adjustment factors reported in this study (Tables I and V) are suggestive nonetheless.

Though the writer claims little competence in the field of ANS neurophysiology, recent experimental data have been reported, suggesting that the submarine atmosphere may induce abnormally "tuned" or activation states of the ANS system (to use Gellhorn's language, 1957). There is now evidence from animal experimentation (Gellhorn, 1953) that hypothalamic functions are affected by breathing 10% carbon dioxide, the behavioral concomitants being characterized as heightened susceptibility to nocioceptive stimuli. Although presumed to be non-toxic, the carbon dioxide levels in the atmosphere of the modern submarine is typically many times higher than is found in normal breathing air. It therefore seems plausible that the activation level of the ANS may be altered as a result. This possibility exists because of the known relationship between hypothalamic function and the ANS, particularly the sympathetico-adrenomedullary system. First animal, then human experimentation is needed to examine these relationships.

SUMMARY

The purpose of the study was to determine the relationship between psychophysiological response patterns produced by laboratory-induced stress and recoverability following stress and individual differences in adjustment to prolonged submarine confinement. The 170 subjects were enlisted men from two crews of one Fleet Ballistic Missile Submarine.

All the subjects were exposed in the same order to two laboratory-induced stress situations. The first stress situation involved the measurement of electrodermal conductance (EDC), Palmar, before, during, and following the instructions to "hyperventilate three times and hold the breath as long as possible". The scores computed for the first experiment were as follows: (numbers indicating the number of the variables in Tables I and II) Basal conductance level (1.1), average deviation of conductance of EDC, (1.2), percentage displacement during hyperventilation and breathholding (1.3), proportion of EDC change recovered following breathholding (1.4), the ratio of EDC displacement to EDC recovery (1.5), the slope of the resistance curve during breathholding (1.6), the amplitude and duration of the GSR immediately following breathholding (1.7), and breathholding time (1.8).

The second stress situation involved the discrimination of the relative intensities of two lights, the intensity differences being subtly reduced as the sixteen trials progressed. The derived scores obtained from the second stress experiment were as follows: The mean magnitude of GSR obtained during minimal stress (large light intensity differences) (2.1), the same score for maximum stress (small stimulus differences) (2.2), the percentage change in GSR's for the two conditions (2.3), the proportion of EDC recovered following stress (2.4), the mean discrimination time for easily discriminable trials (2.5), and the percentage increase in discrimination time during the maximum stress trials (2.6). Paper-and-pencil tests of verbal intelligence, neuroticism, and motivation (3.1, 3.2, 3.3 in that order) were also included. Finally two adjustment criteria in factor score

form (4.1 and 4.2) and derived from a factor analysis of twenty trait ratings obtained during several submerged cruises were also included in the battery of test and measures. A 19x19 correlation matrix was computed and factor analyzed using the group centroid method.

Examination of the structure of the five factors extracted from the correlation matrix indicated that Factor I identified less adequately adjusted men who tended to show low basal EDC measures, to show high ANS lability and to show relatively complete resistance recovery following stress. On the other hand, optimally adjusted submariners identified by Factor II were characterized by low EDC displacement and high recovery rates to both kinds of laboratory-induced stress. They tended also to have high verbal intelligence and a low incidence of neurotic symptoms.

Factor III is identified wholly by high EDC recovery irrespective of the EDC level or amount of displacement to the stress situation. Factor IV is identified by high positive loadings of verbal intelligence, long breathholding time, but with low EDC level, displacement, and recovery. This factor was labeled Autonomic Feedback on the basis that the noxious sensations of breathholding may have affected the amount of ANS displacement and recovery which in turn affected the subjective experience of breathholding to give a somewhat obscure feedback situation. Finally, weighted by the motivation test score, the person would obtain a high score in Factor V by virtue of high EDC displacement to breathholding with incomplete EDC recovery, though the resistance which is recovered is achieved at an accelerated rate. High ANS responsivity specifically to breathholding stress seemed to characterize the final factor.

Predictive validity of the identifying variables for certain of the factors was examined by computing multiple correlations with one or another of the two factor score criteria. These multiple correlations (Table V) were ranged from .50 to .60. The magnitude of the correlations suggest that usefulness of these kinds of measures in predicting individual differences in adjustment to stresses existing during prolonged submergence.

Although additional validation data are necessary before these kinds of psychophysiological measures can be recommended as usefully predictive, nonetheless, the data in this study argue that individual differences in ANS response patterns to laboratory-induced stress coupled with personality test data yield factors which have useful predictive validity. The structure of these factors moreover suggests relatively unexplored dimensions useful in personality assessment for hazardous duty.

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APPENDIX A

F_1, Tentative Label: Favorable Submariner Trait Configuration I

Loading[a]	Statement of Content[b]
828	Favorable performance
657	Adequately motivated
562	Attitudes improve during rehabilitation
546	Favorable attitudes toward Navy
520	Self confident
500	Likable
463	High leadership ability
462	Emotionally stable
461	Adaptable to change
460	Favorable attitudes toward FBM
405	Rated somewhat aggressive
404	Rated adaptable by officers

APPENDIX A (Continued)

F_2, Tentative Label: Favorable Submariner Trait Configuration II

Loading[a]	Statement of Content[b]
906	Not excitable
862	Not tense
691	Not anxious
678	Adaptable to change
674	Likable
638	Happy
634	Emotionally stable
541	Favorable attitudes toward FBM
525	Self confident
511	Favorable attitudes toward Navy
494	Rated high as a submariner
474	Highly motivated

[a]Decimals are omitted.

[b]Statement of content takes into account the sign of the factor loading.

Tables abstracted from USN Med. Res. Lab. Rep. No. 388, 1962

APPENDIX B

Transformation Matrix Used for the Orthogonal Rotations

	F_1''	F_2'	F_3''	F_4'''	F_5''
F_1	.794	.073	.215	-.124	.550
F_2	.126	.906	0	.333	-.227
F_3	-.405	.256	.747	-.432	.161
F_4	.210	-.328	.629	.555	-.379
F_5	-.382	0	0	.616	.689